THE OSMOTIC CONCENTRATION OF THE TISSUE FLUIDS OF JAMAICAN MONTANE RAIN-FOREST VEGETATION[1]

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I. Introductory Remarks

Purpose of Investigation.—This paper is one of a series in which various problems involving the investigation of the osmotic pressure or osmotic concentration of the fluids of plant tissues are treated. Specifically it presents an extensive series of determinations of the freezing-point lowering of the extracted leaf sap of plants from the Blue Mountains of Jamaica, discusses the differences in these values in their relation to local differences in the environmental complex, and briefly compares the series as a whole with others now available.

In another place (Harris, Lawrence and Gortner, 1916) we have put forward in detail the arguments for the carrying out of such studies as a regular part of systematic and thoroughgoing phytogeographical investigation. It seems unnecessary, therefore, to repeat these arguments here.

After completing a series of determinations of the osmotic concentration of the tissue fluids of a number of species of plants from the southwestern deserts, in the vicinity of the Desert Laboratory during the winter and spring months of 1914, and comparing them (Harris, Lawrence and Gortner, 1915) with a series made in the more mesophytic habitats in the neighborhood of the Station for Experimental Evolution on Long Island, the next most desirable step seemed to be the investigation of the sap properties of the plants of an extremely hygrophytic region.

Since such field studies could be most conveniently carried out during the winter months, at a time when we could be absent from

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experiments under way at the Station for Experimental Evolution, it was quite natural to think of the Tropical Laboratory at Cinchona, established by the New York Botanical Garden and later maintained by the British Association for the Advancement of Science and the Jamaican local government, as the most promising locus for such work. This station presents the advantages of furnishing living quarters and laboratory space on the edge of a primaeval montane rain forest within twenty miles of a point where ice, essential for the preliminary freezing of tissues for the extraction of sap, can be obtained. This was quite successfully packed over the Port Royal Mountains, through the Yallahs river valley and up to Cinchona on mule back by negro helpers.

To Professor Bower and the other members of the British Association committee in charge of the Tropical Laboratory at Cinchona and to Mr. Wm. Harris, F.L.S., superintendent of public gardens and plantations, we are indebted not only for the use of the laboratory but for other courtesies that added to the success and pleasure of our work while in Jamaica.

Characteristics of the Region Investigated.—The higher portions of the Blue Mountains are characterized by a relatively low but uniform temperature, by a large and well-distributed rainfall, accompanied by much fog and cloudiness and high relative humidity.

The rainfall upon the northern is far greater than that upon the southern slopes of the mountains. The averages given by Shreve (1914) for the upper mountains, in which all our collections were made, are:

Cinchona	105.70 inches
New Haven Gap	113.85 inches
Blue Mountain Peak	130.48 inches

Notwithstanding the heavy rainfall there are neither ponds nor constant streams above 4,500 feet, but in places there are depressions on the higher portions of the main ridge of the mountains which are developed as sphagnum bogs. Below 4,500 feet the water emerges to feed numerous swift mountain streams. Transient water courses are found much higher.

While the rainfall is large it is not comparable with the maximum precipitations known in other tropical plant environments. Furthermore the amount varies greatly from year to year, both in quantity

and distribution. Thus Shreve (1914), in working through the records which have been kept at Cinchona for the past thirty-nine years, finds variation in the total annual precipitation from about 59 to about 179 inches. In October, the rainfall has varied from about 3 to 43 inches. In February, precipitation has ranged from less than an inch to nearly 13 inches. At New Haven Gap during the three months of April, May and June, 1892, there was not a measurable amount of rainfall, whereas during the same three months in 1894 there fell 62 inches of water.

Thus the vegetation is by no means free from occasional periods of drought.

Notwithstanding this fact, moisture is so great in quantity and so uniform in distribution that it supports a dense evergreen arborescent and herbaceous vegetation, a large proportion of the constituent species of which are of a pronouncedly hygrophilous character. As a factor in the development and maintenance of the vegetation, the distribution as well as the actual quantity of the precipitation is a factor of great importance. Precipitation is almost exclusively in the form of light showers of brief duration or gentle and long continued rain, but never in the torrential downpours so characteristic of deserts and tropical lowlands. Transient showers of too brief duration to be registered as giving a measurable quantity of rainfall are frequent. Shreve gives a table showing that at Cinchona on an average from one third to two thirds of the days of the twelve individual months of the year have a measurable precipitation.

On the northern slopes fog is prevalent from below 4,500 feet to the summits of the highest peaks from 10 a. m. to 4 p. m. on a large proportion of the days during all the months of the year, with the possible exceptions of July and August. Fog is much less frequent on the southern exposure of the mountains, but even here it is often seen on the upper slopes, and a large percentage of the days are cloudy or partially cloudy. Shreve, after nearly a year's residence in the Blue Mountains, describes the condition as follows: "The typical course of the day's weather is: clear from sunrise until 9 to 11 a. m., intermittently or entirely cloudy until nearly sunset, with two or three hours of fog in the mid-day or early afternoon, the sun setting clear. Rain usually occurs in the mid-day or early afternoon and the night is clear."

As a consequence of the high and well-distributed rainfall and

the prevalence of fog, atmospheric humidity is high, ranging from about 80 to about 89 percent in the various months of the year, with an annual average of about 84 percent.

Temperature is low and remarkably uniform throughout the year. At a depth of six feet at Cinchona the monthly mean soil temperature is 16.4° C., with a mean annual range of 1.5°. For air temperatures the annual mean is 16.0°, the annual mean range 2.9°, and the average daily range 6.6°.

Our work was of necessity carried out within a radius sufficiently narrow to permit of the collections being made afoot, and brought back to the Laboratory for freezing within a few hours. Materials were drawn from the territory made accessible by the trail from Cinchona through Morce's Gap to a point somewhat south of Vinegar Hill, by that from Morce's Gap to John Crow Peak, by that from Cinchona to a point on one of the Green River affluents south of New Haven Gap, and by that from Cinchona through New Haven Gap to the lower slopes of Sir John Peter Grant Peak. Collections were by no means limited to the immediate vicinity of the trails, but were also drawn from the denser parts of the jungle, which was pretty thoroughly penetrated in various directions.

While a few determinations are based upon collections made between 5,500 and 6,000 feet, especially from New Haven Gap and from the slopes and summit of John Crow Peak, the main bulk of our constants are based on samples gathered between 4,500 and 5,500 feet. Below 4,500 feet conditions change rapidly. Thus at Resource, one mile south of Cinchona and 1,300 feet lower (3,700 as compared with 5,000 feet), the mean rainfall is about 68 as compared with about 106 inches per annum at the Laboratory. The fogs which are so characteristic a feature of the northern slopes of the mountains, and which roll over the ridges from the windward sides, are dissipated on the lower leeward (southern) slopes. Thus conditions are not merely warmer but far drier. Here, too, much of the natural vegetation, which in most of the area studied was in a primaeval condition, has been replaced or distinctly modified by agricultural operations—chiefly the planting of Arabian coffee, which thrives and because of the superiority of the product is commercially profitable in a region so broken as to be useful for only the more valuable hand-tilled crops.

Materials and Methods.—In order that the constants of the present study may be comparable with those derived from other regions it

has seemed desirable to limit the determinations to those based on terrestrial plants. Epiphytic forms are reserved for treatment, with comparable forms from other regions, in a special publication.

In a habitat in which erosion is so active, epiphytes are frequently brought to the ground by the fall of trees. Furthermore, conditions on the litter-covered forest floor, on large fallen and partially decayed logs, and on the higher limbs of trees, differ by only imperceptible degrees. Thus our separation of the epiphytes from the terrestrial forms has of necessity been somewhat arbitrary.

All of the Bromeliaceae we have omitted from the present treatment.

Of the Orchidaceae we are publishing determinations for the terrestrial *Prescottia stachyoides* and *Stenorrhynchos speciosum*. *Epidendrum verrucosum* we have included since we always collected it growing in soil on rocky banks. Fawcett and Rendle give its occurrence as "on trees, rocks and dry banks." *Epidendrum imbricatum*, which Fawcett and Rendle cite as occurring on trees and which we found growing as a typical epiphyte, we have omitted from the present paper. The parasites have been discussed in an earlier number of this Journal (Harris and Lawrence, 1916).

The species of the genus *Peperomia* have caused considerable trouble. They may be either truly epiphytic, rooted in the masses of leaf mould on fallen logs, or terrestrial in peaty soil. So far as we were able to observe *P. stellata* is always terrestrial. We have therefore included it, but have reserved all other species of *Peperomia* for a special memoir on epiphytic vegetation.

Blakea trinervia and *Tradescantia multiflora*, which may be either rooted in the soil or epiphytic, have been included in this paper.

Methods.—The methods employed were those of previous papers of this series. Considerable difficulty of a purely physical sort was encountered in the collection of the samples. Much of the work had to be carried out in the rain or in tangled vegetation dripping wet from recent rain or fog. It was often necessary, therefore, for one worker to crouch under a poncho and wipe each leaf dry with absorbent tissue before it was placed in the collecting tubes for preliminary freezing (Gortner and Harris, 1914).

The frozen tissue was squeezed with the greatest thoroughness possible in a press with a powerful hand screw to avoid any possibility of the differential extraction of sap as noted by Dixon and Atkins (1913) and ourselves (Gortner, Lawrence and Harris, 1916).

The freezing-point lowering of the filtered sap was determined by means of ether or carbon bisulphide vaporized by a dried air current in a vacuum jacketed bulb.

The results are expressed in terms of freezing-point lowering, Δ, corrected for undercooling, and in atmospheres pressure P from a published table (Harris and Gortner, 1914).

Classification of Habitats.—In these studies it has been our policy to adopt in so far as possible the classification of plant habitats drawn up by specialists in ecology or phytogeography. Such a course makes for simplicity and lack of confusion in the literature, lends added value to such habitat studies as have already been made by correlating with them new kinds of observations, and finally precludes any possibility of bias in the classification of determinations in a way to make them agree with any preconceived theory.

For the Blue Mountain region it has been possible to follow the classification presented in the splendid work of our colleague Forrest Shreve (1914) whose extended experience in the montane region of Jamaica and whose analyses of the previous scattered literature and meteorological data have made it unnecessary for us to go back of his large publication on the region.

For descriptive details presented in a most readable manner and a wealth of carefully selected illustrations the reader must turn to Shreve's book. Here only the most salient and essential points will be set forth.

The fundamental division is that into the two main slopes of the mountain chain. These are designated as windward and leeward rather than northern and southern to emphasize the predominant influence of the moisture-laden trade winds in determining the characteristics of the vegetation. The subdivision of the two main slopes is made on the basis of topography, into ravines, slopes and ridges. In carrying out our work we have found it desirable to emphasize certain of these regions at the expense of others. Such descriptive details as are essential will be given under the discussions of the individual habitats.

We have not found it practicable to consider individually all of the five types of habitats recognized by Shreve.

Because of the morphologically xerophilous character of its scrub vegetation we desired to investigate rather fully the sap properties of the "ruinate" of the once cleared southern slopes. This seemed

to us more important than a consideration of the primaeval forest of the leeward slopes. As the other extreme in the vegetation of the southern side of the ridge, the vegetation of the leeward ravine seemed desirable.

In dealing with the collections from the windward sides of the mountains we have not found it practicable to follow the treatment accorded them by Shreve who discusses the ravines and the slopes separately. The two habitats blend quite imperceptibly into each other. The distinction between the vegetation of the two has seemed to us to be primarily one of the loftiness of the trees and the abundance of the extremely hygrophilous ferns, mosses, and hepatics. While an investigation of the concentration of the sap in the bryophytes and filmy ferns that are so characteristic a feature of the more hygrophytic habitats would be of great interest, we preferred to devote our time to the study of arborescent and herbaceous seed plants of the type to be met with in other regions with which comparisons are to be drawn.

For this reason we have treated the collections from the leeward ravines and leeward slopes together.

Our collections have, therefore, been distributed among the following habitats.

I. Ruinate of the Leeward Slopes.
II. Leeward Ravines.
III. Ridges.
IV. Windward Slopes and Ravines.

The distinction between these habitats is by no means always sharply marked. Ravines and ridges are merely the extremes of the topographic series. Between them and the intervening slopes there is, from the purely topographical side, no sharp line of demarcation.

Furthermore, the habitat distinctions are not based primarily upon the substratum but upon meteorological conditions. Air movements undoubtedly play a considerable rôle in determining the character of the vegetation. Thus fog is often blown over the main ridge, rolling down the leeward slopes for some distance, to be dissipated below. The vegetation of the ridges which are at the same time gaps exhibits many of the characteristics of the ravine.

In view of these facts it is altogether improbable that any two botanists would agree exactly upon the classification into habitats of a series of 398 collections—the number upon which the present discussion is based. While in some cases our disposition of a given

determination may have been somewhat arbitrary, it was not influenced in any measure by the magnitude of the constant, for the collections were all classified before the corrected freezing point lowerings were calculated. Thus there seems no possibility of personal equation influencing the results.

II. Presentation of Data

1. *Ruinate of Leeward Slopes*

The slopes which were once cleared for coffee or cinchona planting but have since been abandoned—in a large part, long ago—are known locally as ruinate.

The ruinate is characterized, as is of course to be expected, by a relatively large number of introduced, in some cases widespread, species.

While the ruinate has been described by writers as a xerophilous scrub formation, it occupies an area supplied with an abundance of precipitation, quite as much in fact as the primaeval forest of the same slopes.

In so far as the conditions are really those of a xerophytic environment they must be due to (*a*) edaphic conditions influencing water absorption, and (*b*) to the lowness and openness of the stand, permitting free air movements with consequent increased transpiration.

The classification of this vegetation as xerophilous is due, we believe, to two factors. First, in contrast to the extreme hygrophily of the ravines of both leeward and windward slopes, the structurally really mesophytic species of the ruinate have a far more xerophytic aspect than they would if growing in a region of more moderate humidity, just as they would pass for decidedly mesophytic types in deserts like those of southern Arizona. Second, there are a number of truly desert species which have a profound effect upon the physiognomy of the vegetation. Agave is not common but *Yucca aloifolia* is frequently seen. *Baccharis scoparia* is probably the chief form lending a xerophytic aspect to the vegetation.

What we have just said concerning the ruinate applies to only the areas in the neighborhood of 5,000 feet where our determinations were made. Below this level, and especially on the southern face of the Port Royal mountains, conditions are much drier and the truly desert species more numerous.

A habitat in which such introduced forms as *Daucus Carota*, *Pastinaca sativa* and *Plantago lanceolata* thrive, and in which occurs a number of species common to this and one or more of the hygrophytic habitats, can hardly be regarded as truly xerophytic.

The determinations from the ruinate are given in the accompanying protocol.

Since the data are presented in a uniform way for the four habitats, an explanation of the form of these lists may be given here.

The plants are first of all divided into ligneous and herbaceous. Under each of these groups the species are, for convenience of reference, arranged alphabetically. The values of Δ and P opposite the species names are averages whenever more than a single determination for the species could be secured in the habitat. In such cases the values are designated by bars, $\bar{\Delta}$ and $\bar{P}$, the individual determinations upon which these averages are based with their dates of collection are given beneath the species name and its average constants for the habitat in question. In cases in which only a single determination could be secured, the values of Δ and P are given, with the date of collection, in place of the average value.

Ligneous Plants

Asclepias physocarpa (E. Meyer) Schlecht. Feb. 28, $\Delta = 0.86$, $P = 10.4$

Baccharis scoparia (L.) Sw. $\bar{\Delta} = 1.18$, $\bar{P} = 14.2$

Feb. 6, $\Delta = 1.10$, $P = 13.3$; Feb. 18, $\Delta = 1.15$, $P = 13.8$; Feb. 24, $\Delta = 1.28$, $P = 15.4$.

Bidens incisa (Ker.) G. Don Feb. 7, $\Delta = 0.91$, $P = 11.0$

Bocconia frutescens L. $\bar{\Delta} = 0.91$, $\bar{P} = 11.0$

Feb. 5, $\Delta = 0.82$, $P = 9.9$; Feb. 28, $\Delta = 0.99$, $P = 12.0$.

Borreria verticillata (L.) Meyer Feb. 5, $\Delta = 0.68$, $P = 8.2$

Caesalpinia sepiaria Roxb. $\bar{\Delta} = 0.97$, $\bar{P} = 11.7$

Mar. 6, $\Delta = 0.95$, $P = 11.5$; Mar. 6, $\Delta = 0.98$, $P = 11.8$.

Cestrum odontospermum Jacq. Mar. 6, $\Delta = 0.99$, $P = 11.9$

Citharexylum caudatum L. Mar. 18, $\Delta = 2.03$, $P = 24.4$

Coffea arabica L. Mar. 6, $\Delta = 1.29$, $P = 15.5$

Cracca grandiflora (Vahl.) Kuntze Feb. 5, $\Delta = 0.85$, $P = 10.3$

Crotalaria Saltiana Andr. Feb. 8, $\Delta = 0.82$, $P = 9.9$

Dodonaea jamaicensis DC. $\Delta = 1.18$, $\bar{P} = 14.2$

Feb. 5, $\Delta = 1.05$, $P = 12.7$; Feb. 7, $\Delta = 1.09$, $P = 13.1$; Feb. 26, $\Delta = 1.41$, $P = 16.9$.

Duranta repens L. $\bar{\Delta} = 1.26$, $\bar{P} = 15.2$

Feb. 28, $\Delta = 1.29$, $P = 15.5$; Feb. 28, $\Delta = 1.25$, $P = 15.0$; Mar. 6, $\Delta = 1.25$, $P = 15.1$.

Echites torosa Jacq. Feb. 5, $\Delta = 1.08$, $P = 13.0$

Eroteum theoides Sw. (Cleyera theoides (Sw.) Choisy) $\bar{\Delta} = 1.14$, $\bar{P} = 13.8$

Feb. 14, $\Delta = 1.03$, $P = 12.4$; Feb. 28, $\Delta = 1.15$, $P = 13.9$; Mar. 6, $\Delta = 1.19$; $P = 14.3$; Mar. 6, $\Delta = 1.20$, $P = 14.5$.

Young leaves were also taken Feb. 14 and gave: $\Delta = 1.27$, $P = 15.3$.

Eupatorium glandulosum H. B. K. $\bar{\Delta} = 0.82$, $\bar{P} = 9.8$

Feb. 28, $\Delta = 0.82$, $P = 9.8$; Mar. 6, $\Delta = 0.81$, $P = 9.8$.

Eupatorium heteroclinium Griseb. $\bar{\Delta} = 1.10$, $\bar{P} = 13.2$

Feb. 5, $\Delta = 1.17$, $P = 14.0$; Feb. 7, $\Delta = 1.03$, $P = 12.4$.

Eupatorium triste DC. Feb. 5, $\Delta = 1.08$, $P = 13.0$

Garrya Fadyenii Hook. $\bar{\Delta} = 2.13$, $\bar{P} = 25.6$

Feb. 7, $\Delta = 1.92$, $P = 23.0$; Feb. 14, $\Delta = 2.34$, $P = 28.1$.

Iresine paniculata (L.) Kuntze Feb. 5, $\Delta = 0.85$, $P = 10.3$

Lantana Camara L. $\bar{\Delta} = 0.81$, $\bar{P} = 9.8$

Feb. 5, $\Delta = 0.74$, $P = 9.0$; Feb. 14, $\Delta = 0.94$, $P = 11.3$; Mar. 6, $\Delta = 0.76$, $P = 9.2$.

Lantana reticulata Pers. Feb. 28, $\Delta = 0.76$, $P = 9.2$

Lantana stricta Sw. $\bar{\Delta} = 0.73$, $\bar{P} = 8.8$

Feb. 5, $\Delta = 0.66$, $P = 8.0$; Feb. 14, $\Delta = 0.76$, $P = 9.1$; Mar. 6, $\Delta = 0.77$, $P = 9.2$.

Mecranium virgatum (Sw.) Triana Feb. 28, $\Delta = 0.71$, $P = 8.6$

Miconia quadrangularis (Sw.) Naud. Mar. 6, $\Delta = 0.91$, $P = 10.9$

Micromeria obovata Benth. Feb. 7, $\Delta = 0.76$, $P = 9.1$

Oreopanax capitatum (Jacq.) Dec. & Pl. $\bar{\Delta} = 1.59$, $\bar{P} = 19.1$

Feb. 14, $\Delta = 1.66$, $P = 19.9$; Feb. 28, $\Delta = 1.59$, $P = 19.1$; Mar. 18, $\Delta = 1.53$, $P = 18.3$.

Young leaves taken with the sample of March 18 gave: $\Delta = 1.14$, $P = 13.8$

Passiflora edulis Sims Mar. 18, $\Delta = 1.58$, $P = 19.0$

Phenax hirtus (Sw.) Wedd. Feb. 28, $\Delta = 0.76$, $P = 9.2$

Psychotria corymbosa Sw. Feb. 14, $\Delta = 0.82$, $P = 9.9$

Quercus sp. Mar. 19, $\Delta = 1.10$, $P = 13.3$

Rapanea ferruginea (R. & P.) Mez Feb. 14, $\Delta = 1.18$, $P = 14.2$

Relbunium hypocarpium (L.) Hemsl. Feb. 5, $\Delta = 0.76$, $P = 9.2$

Rosa laevigata Michx. Feb. 8, $\Delta = 1.50$, $P = 18.0$

Smilax celastroides Kunth Feb. 14, $\Delta = 1.38$, $P = 16.6$

Young leaves gave: $\Delta = 1.14$, $P = 13.7$.

Triumfetta semitriloba Jacq. Feb. 8, $\Delta = 0.73$, $P = 8.8$

Vaccinium meridionale Sw. $\bar{\Delta} = 1.25$, $\bar{P} = 15.1$

Feb. 7, $\Delta = 1.17$, $P = 14.1$; Feb. 18, $\Delta = 1.25$, $P = 15.1$; Feb. 24, $\Delta = 1.34$, $P = 16.1$.

Vernonia divaricata Sw. $\bar{\Delta} = 1.14$, $\bar{P} = 13.7$

Feb. 14, $\Delta = 1.21$, $P = 14.6$; Feb. 28, $\Delta = 1.17$, $P = 14.0$; Mar. 6, $\Delta = 1.03$, $P = 12.4$.

Viburnum alpinum Macf. $\bar{\Delta} = 1.36$, $\bar{P} = 16.4$

Feb. 5, $\Delta = 1.29$, $P = 15.5$; Feb. 28, $\Delta = 1.42$, $P = 17.1$; Mar. 6, $\Delta = 1.37$, $P = 16.5$.

Yucca aloifolia L. $\bar{\Delta} = 1.63$, $\bar{P} = 16.3$
Feb. 6, $\Delta = 1.78$, $P = 21.4$; Feb. 28, $\Delta = 1.45$, $P = 7.4$; Mar. 6, $\Delta = 1.66$, $P = 20.0$.
The values given are those for the fully matured leaves. A determination from the yellowish leaves which were past their period of maximum physiological activity was taken on Feb. 6 and gave: $\Delta = 1.55$, $P = 18.7$. In the collection of Feb. 28 the young leaves gave $\Delta = 0.79$, $P = 9.5$. Juice extracted from the axis of the plants from which the collection of Feb. 6 was made gave $\Delta = 0.96$, $P = 11.6$.

HERBACEOUS PLANTS

Ambrosia peruviana Willd. Feb. 28, $\Delta = 1.02$, $P = 12.2$
Aristea compressa Buch. Feb. 5, $\Delta = 0.72$, $P = 8.7$
Begonia obliqua L. $\bar{\Delta} = 0.36$, $\bar{P} = 4.3$
Feb. 8, $\Delta = 0.35$, $P = 4.2$; Feb. 14, $\Delta = 0.36$, $P = 4.3$; Feb. 28, $\Delta = 0.30$, $P = 3.7$; Mar. 6, $\Delta = 0.41$, $P = 5.0$.
Bidens pilosa L. Feb. 7, $\Delta = 0.74$, $P = 8.9$
Bryophyllum pinnatum (Lam.) Kurz. $\bar{\Delta} = 0.40$, $\bar{P} = 4.7$
Feb. 5, $\Delta = 0.38$, $P = 4.5$; Mar. 6, $\Delta = 0.41$, $P = 4.9$.
Cionosicys pomiformis (Macf.) Griseb. Mar. 18, $\Delta = 1.06$, $P = 12.8$
Daucus Carota L. $\bar{\Delta} = 1.16$, $\bar{P} = 14.0$
Feb. 5, $\Delta = 1.01$, $P = 12.1$; Mar. 6, $\Delta = 1.31$, $P = 15.8$.
Epidendrum verrucosum Sw. $\bar{\Delta} = 0.55$, $\bar{P} = 6.6$
Feb. 6, $\Delta = 0.58$, $P = 7.0$; Mar. 6, $\Delta = 0.55$, $P = 6.6$; Mar. 16, $\Delta = 0.51$, $P = 6.2$.
Hedychium flavum Roxb. $\times$ *Hedychium Gardnerianum* Rosc. (?)
Feb. 6, $\Delta = 0.67$, $P = 8.1$
Lycopodium clavatum L. $\bar{\Delta} = 0.79$, $\bar{P} = 9.5$
Feb. 18, $\Delta = 0.80$, $P = 9.6$; Feb. 24, $\Delta = 0.78$, $P = 9.4$.
Lycopodium Fawcettii Lloyd & Underw. $\bar{\Delta} = 0.89$, $\bar{P} = 10.6$
Feb. 18, $\Delta = 0.87$, $P = 10.4$; Feb. 24, $\Delta = 0.90$, $P = 10.8$.
Maurandia erubescens (Zucc.) A. Gray. $\bar{\Delta} = 0.84$, $\bar{P} = 10.1$
Feb. 5, $\Delta = 0.86$, $P = 10.3$; Feb. 14, $\Delta = 0.80$, $P = 9.7$; Feb. 28, $\Delta = 0.89$, $P = 10.7$; Mar. 6, $\Delta = 0.79$, $P = 9.5$.
Meibornia uncinata (Jacq.) Kuntze (?) Feb. 8, $\Delta = 0.62$, $P = 7.5$
Pastinaca sativa L. $\bar{\Delta} = 1.27$, $\bar{P} = 15.3$
Feb. 14, $\Delta = 1.35$, $P = 16.3$; Mar. 6, $\Delta = 1.18$, $P = 14.2$.
Pilea grandifolia (L.) Blume (?) Feb. 28, $\Delta = 0.66$, $P = 8.0$
Plantago lanceolata L. $\bar{\Delta} = 1.12$, $\bar{P} = 13.5$
Feb. 8, $\Delta = 0.95$, $P = 11.5$; Feb. 28, $\Delta = 1.13$, $P = 13.6$; Mar. 6, $\Delta = 1.29$, $P = 15.5$.
Verbena bonariensis L. Feb. 8, $\Delta = 0.94$, $P = 11.3$

II. *The Leeward Ravines*

The ravines, like the slopes, of the leeward side of the mountains receive a lighter rainfall, much less fog, and reciprocally more hours of sunshine, than the windward habitats.

The ravines of the leeward slopes are physiographically similar to those of the windward slopes. Both exhibit a forest covering of irregular canopy of larger trees with rich undergrowth of shrubs. The conspicuous difference between the two is chiefly found in the relative scarcity of epiphytes, both Orchidaceae and Bromeliaceae, and particularly of the most hygrophilous of the pteridophytes and the practical absence of tree ferns in the leeward ravines.

Ligneous Plants

Acalypha virgata L. $\bar{\Delta} = 0.87, \bar{P} = 10.5$
Feb. 11, $\Delta = 0.78, P = 9.4$; Mar. 11, $\Delta = 0.85, P = 10.2$; Mar. 18, $\Delta = 0.98, P = 11.8$.

Acnistus arborescens (L.) Schlecht. Mar. 11, $\Delta = 0.85, P = 10.2$

Besleria lutea L. $\bar{\Delta} = 0.74, \bar{P} = 8.8$
Feb. 11, $\Delta = 0.65, P = 7.8$; Feb. 26, $\Delta = 0.69, P = 8.3$; Mar. 11, $\Delta = 0.85, P = 10.2$; Mar. 18, $\Delta = 0.75, P = 9.0$.

Bocconia frutescens L. $\bar{\Delta} = 0.79, \bar{P} = 9.5$
Feb. 11, $\Delta = 0.75, P = 9.0$; Mar. 11, $\Delta = 0.83, P = 10.0$.
Young leaves taken in the collection of Feb. 11 gave values only slightly lower than those from mature organs, i. e., $\Delta = 0.72, P = 8.6$.

Boehmeria caudata Sw. Mar. 11, $\Delta = 0.86, P = 10.3$

Brunfelsia jamaicensis Griseb. $\bar{\Delta} = 0.79, \bar{P} = 9.4$
Feb. 11, $\Delta = 0.78, P = 9.3$; Mar. 18, $\Delta = 0.79, P = 9.5$.

Cestrum hirtum Sw. $\bar{\Delta} = 0.73, \bar{P} = 8.8$
Feb. 11, $\Delta = 0.74, P = 8.9$; Mar. 18, $\Delta = 0.72, P = 8.7$.

Cinchona Sp. $\bar{\Delta} = 0.92, \bar{P} = 11.1$
Feb. 11, $\Delta = 0.97, P = 11.6$; Mar. 18, $\Delta = 0.87, P = 10.5$.

Clibadium terebinthinaceum (Sw.) DC. $\bar{\Delta} = 0.82, \bar{P} = 9.9$
Feb. 11, $\Delta = 0.72, P = 8.6$; Feb. 26, $\Delta = 0.89, P = 10.7$; Mar. 11, $\Delta = 0.86, P = 10.4$.

Dendropanax arboreum (L.) Dec. & Pl. $\bar{\Delta} = 1.11, \bar{P} = 13.3$
Feb. 11, $\Delta = 1.11, P = 13.3$; Mar. 18, $\Delta = 1.10, P = 13.3$.

Duranta repens L. $\bar{\Delta} = 1.33, \bar{P} = 16.0$
Feb. 11, $\Delta = 1.20, P = 14.4$; Mar. 18, $\Delta = 1.45, P = 17.5$.

Eupatorium glandulosum H. B. K. $\bar{\Delta} = 0.64, \bar{P} = 7.7$
Feb. 26, $\Delta = 0.64, P = 7.7$; Mar. 11, $\Delta = 0.64, P = 7.6$.

Eupatorium riparium Regel $\bar{\Delta} = 0.78, \bar{P} = 9.3$
Mar. 11, $\Delta = 0.77, P = 9.2$; Mar. 18, $\Delta = 0.78, P = 9.4$.

Fuchsia corymbiflora R. & P. $\bar{\Delta} = 0.67, \bar{P} = 8.1$
Mar. 11, $\Delta = 0.73, P = 8.8$; Mar. 11, $\Delta = 0.70, P = 8.5$; Mar. 18, $\Delta = 0.57, P = 6.9$.

Garrya Fadyenii Hook. Feb. 26, $\Delta = 2.23, P = 26.8$

Gesneria alpina Urban Mar. 11, $\Delta = 0.52, P = 6.3$

Guarea Swartzii DC. $\bar{\Delta} = 0.90, \bar{P} = 10.9$
Mar. 11, $\Delta = 0.79, P = 9.6$; Mar. 18, $\Delta = 1.02, P = 12.3$; Mar. 18, $\Delta = 0.90, P = 10.8$.

Hedyosmum nutans Sw. Feb. 26, $\Delta = 0.73$, $P = 8.8$

Iresine paniculata (L.) Kuntze $\bar{\Delta} = 0.96$, $\bar{P} = 11.6$

Feb. 11, $\Delta = 0.89$, $P = 10.8$; Feb. 26, $\Delta = 0.97$, $P = 11.7$; Mar. 11, $\Delta = 1.03$, $P = 12.4$.

Lantana Camara L. $\Delta = 0.69$, $\bar{P} = 8.2$

Feb. 11, $\Delta = 0.64$, $P = 7.6$; Feb. 26, $\Delta = 0.73$, $P = 8.8$; Mar. 11, $\Delta = 0.68$, $P = 8.2$; Mar. 18, $\Delta = 0.69$, $P = 8.3$.

Phenax hirtus (Sw.) Wedd. $\bar{\Delta} = 0.77$, $\bar{P} = 9.2$

Feb. 26, $\Delta = 0.74$, $P = 8.9$; Mar. 11, $\Delta = 0.79$, $P = 9.5$.

Phoebe montana (Sw.) Griseb. Feb. 11, $\Delta = 1.02$, $P = 12.3$

Pilea Weddellii Fawc. & Rendle Feb. 26, $\Delta = 0.71$, $P = 8.5$

Piper hispidum Sw. Mar. 18, $\Delta = 0.67$, $P = 8.0$

Psychotria corymbosa Sw. $\bar{\Delta} = 0.68$, $\bar{P} = 8.1$

Feb. 11, $\Delta = 0.66$, $P = 7.9$; Feb. 26, $\Delta = 0.69$, $P = 8.3$.

Rapanea ferruginea (R. & P.) Mez Feb. 26, $\Delta = 1.10$, $P = 13.2$

Young leaves gave: $\Delta = 1.09$, $P = 13.1$.

Rubus jamaicensis Sw. Mar. 18, $\Delta = 1.33$, $P = 16.0$

Senecio Swartzii DC. Mar. 18, $\Delta = 0.66$, $P = 7.9$

Solandra grandiflora Sw. $\bar{\Delta} = 0.82$, $\bar{P} = 9.8$

Mar. 11, $\Delta = 0.79$, $P = 9.5$; Mar. 18, $\Delta = 0.84$, $P = 10.1$.

Tovaria pendula R. & P. Mar. 11, $\Delta = 0.94$, $P = 11.3$

Turpinia occidentalis (Sw.) G. Don Mar. 18, $\Delta = 1.06$, $P = 12.8$

Viburnum villosum Sw. Mar. 18, $\Delta = 1.15$, $P = 13.9$

Herbaceous Plants

Anthurium scandens (Aubl.) Engler $\bar{\Delta} = 0.52$, $\bar{P} = 6.3$

Feb. 11, $\Delta = 0.51$, $P = 6.1$; Mar. 11, $\Delta = 0.53$, $P = 6.4$.

Begonia obliqua L. $\bar{\Delta} = 0.37$, $\bar{P} = 4.5$

Feb. 26, $\Delta = 0.35$, $P = 4.2$; Mar. 11, $\Delta = 0.39$, $P = 4.7$.

Cionosicys pomiformis (Macf.) Griseb. $\bar{\Delta} = 0.69$, $\bar{P} = 8.4$

Mar. 11, $\Delta = 0.66$, $P = 8.0$; Mar. 11, $\Delta = 0.66$, $P = 8.0$; Mar. 18, $\Delta = 0.76$, $P = 9.1$.

Elaphoglossum latifolium (Sw.) J. Sm. Feb. 11, $\Delta = 0.78$, $P = 9.4$

Epidendrum verrucosum Sw. $\bar{\Delta} = 0.51$, $\bar{P} = 6.1$

Mar. 11, $\Delta = 0.50$, $P = 6.0$; Mar. 18, $\Delta = 0.51$, $P = 6.2$.

Liabum umbellatum (L.) Sch. Bip. $\bar{\Delta} = 0.67$, $\bar{P} = 8.1$

Mar. 11, $\Delta = 0.67$, $P = 8.0$; Mar. 18, $\Delta = 0.67$, $P = 8.1$.

Maurandia erubescens (Zucc.) A. Gray $\bar{\Delta} = 0.80$, $\bar{P} = 9.7$

Feb. 26, $\Delta = 0.75$, $P = 9.0$; Mar. 11, $\Delta = 0.80$, $P = 9.6$; Mar. 18, $\Delta = 0.86$, $P = 10.4$.

Pastinaca sativa L. Mar. 18, $\Delta = 1.16$, $P = 14.0$

Peperomia stellata (Sw.) A. Dietr. $\bar{\Delta} = 0.43$, $\bar{P} = 5.2$

Feb. 11, $\Delta = 0.42$, $P = 5.0$; Feb. 26, $\Delta = 0.40$, $P = 4.8$; Mar. 11, $\Delta = 0.41$, $P = 5.0$; Mar. 18, $\Delta = 0.50$, $P = 6.0$.

Pilea grandifolia (L.) Blume $\bar{\Delta} = 0.63$, $\bar{P} = 7.6$

Feb. 11, $\Delta = 0.60$, $P = 7.3$; Feb. 26, $\Delta = 0.70$, $P = 8.4$; Feb. 26, $\Delta = 0.58$, $P = 7.0$.

Senites Zeugites (L.) Nash Feb. 26, $\Delta = 0.69$, $P = 8.4$
Stenorrhynchus speciosus (Jacq.) L.C. Rich. $\bar{\Delta} = 0.52$, $\bar{P} = 6.3$
Feb. 11, $\Delta = 0.54$, $P = 6.5$; Mar. 11, $\Delta = 0.48$, $P = 5.8$; Mar. 18, $\Delta = 0.54$, $P = 6.5$.
Tradescantia multiflora Sw. Mar. 11, $\Delta = 0.39$, $P = 4.7$

III. *The Ridge Forest*

The ridge forest, closely confined to the main ridge of the mountains and to narrow strips along the crests of the water divides on both windward and leeward slopes, is far more open than that of the slopes or ravines. The vegetation is, therefore, not only more exposed to the influence of light, but is much more wind swept than that of the more deeply and densely covered slopes and ravines. This habitat is, therefore, "relatively xerophilous in the entire make up of its vegetation."

The following are the results:

Ligneous Plants

Acalypha virgata L. $\bar{\Delta} = 0.92$, $\bar{P} = 11.1$
Feb. 9, $\Delta = 0.86$, $P = 10.3$; Mar. 9, $\Delta = 0.96$, $P = 11.6$; Mar. 16, $\Delta = 0.95$, $P = 11.4$.
Acnistus arborescens (L.) Schlecht. Mar. 16, $\Delta = 0.97$, $P = 11.7$
Actinophyllum Sciadophyllum (Sw.) R. C. Schneider Mar. 9, $\Delta = 1.24$, $P = 15.0$
Alchornea latifolia Sw. Mar. 4, $\Delta = 0.89$, $P = 10.8$
Brunfelsia jamaicensis Griseb. $\bar{\Delta} = 0.83$, $\bar{P} = 10.0$
Mar. 9, $\Delta = 0.80$, $P = 9.6$; Mar. 9, $\Delta = 0.90$, $P = 10.8$; Mar. 16, $\Delta = 0.80$, $P = 9.6$.
Cestrum hirtum Sw. Mar. 16, $\Delta = 0.83$, $P = 10.0$
Cinchona sp. $\bar{\Delta} = 1.02$, $\bar{P} = 12.3$
Feb. 20, $\Delta = 1.06$, $P = 12.7$; Mar. 4, $\Delta = 0.96$, $P = 11.6$; Mar. 16, $\Delta = 1.05$, $P = 12.6$.
Citharexylum caudatum L. $\bar{\Delta} = 1.92$, $\bar{P} = 23.1$
Feb. 9, $\Delta = 1.95$, $P = 23.4$; Mar. 9, $\Delta = 2.05$, $P = 24.6$; Mar. 9, $\Delta = 1.77$, $P = 21.3$.
Clethra occidentalis (L.) Steud. $\bar{\Delta} = 0.73$, $\bar{P} = 8.8$
Feb. 9, $\Delta = 0.77$, $P = 9.3$; Mar. 16, $\Delta = 0.68$, $P = 8.2$.
Clusia havetioides (Griseb.) Tr. & Pl. Feb. 18, $\Delta = 0.79$, $P = 9.5$
Cyrilla racemiflora L. Feb. 17, $\Delta = 1.18$, $P = 14.2$
To avoid increasing unduly the number of habitats this determination based on material from John Crow Peak has been included in the Ridge Series.
Dendropanax sp. Feb. 9, $\Delta = 1.00$, $P = 12.0$
Dendropanax nutans (Sw.) Dec. & Pl. $\bar{\Delta} = 0.93$, $\bar{P} = 11.2$
Mar. 9, $\Delta = 0.98$, $P = 11.8$; Mar. 16, $\Delta = 0.87$, $P = 10.5$.

Eugenia virgultosa (Sw.) DC. (?) Feb. 9, $\Delta = 0.72$, $P = 8.7$
Eupatorium glandulosum H.B.K. $\bar{\Delta} = 0.72$, $\bar{P} = 8.7$
Feb. 18, $\Delta = 0.76$, $P = 9.2$; Feb. 20, $\Delta = 0.71$, $P = 8.5$; Mar. 9, $\Delta = 0.69$, $P = 8.4$.
Eupatorium parviflorum Sw. Mar. 9, $\Delta = 0.85$, $P = 10.2$
Eupatorium triste DC. $\bar{\Delta} = 1.24$, $\bar{P} = 14.9$
Mar. 9, $\Delta = 1.26$, $P = 15.1$; Mar. 16, $\Delta = 1.21$, $P = 14.6$.
Gesneria alpina Urban $\bar{\Delta} = 0.58$, $\bar{P} = 7.0$
Feb. 9, $\Delta = 0.60$, $P = 7.2$; Mar. 9, $\Delta = 0.56$, $P = 6.8$.
Guarea Swartzii DC. Mar. 9, $\Delta = 1.07$, $P = 12.8$
Gymnanthes elliptica Sw. Mar. 16, $\Delta = 1.00$, $P = 12.0$
Hedyosmum arborescens Sw. $\bar{\Delta} = 0.73$, $\bar{P} = 8.8$
Mar. 16, $\Delta = 0.73$, $P = 8.8$; Mar. 16, $\Delta = 0.73$, $P = 8.8$.
Mecranium purpurascens (Sw.) Triana $\bar{\Delta} = 0.77$, $\bar{P} = 9.3$
Mar. 4, $\Delta = 0.77$, $P = 9.3$; Mar. 4, $\Delta = 0.77$, $P = 9.2$.
Mettenia globosa (Sw.) Griseb. Mar. 16, $\Delta = 0.87$, $P = 10.5$
Miconia quadrangularis (Sw.) Naud. $\bar{\Delta} = 1.00$, $\bar{P} = 12.1$
Feb. 9, $\Delta = 0.87$, $P = 10.5$; Feb. 20, $\Delta = 0.94$, $P = 11.3$; Mar. 4, $\Delta = 1.05$, $P = 12.7$; Mar. 9, $\Delta = 1.11$, $P = 13.4$; Mar. 16, $\Delta = 0.98$, $P = 11.8$; Mar. 16, $\Delta = 1.07$, $P = 12.9$.
Miconia theaezans (Bonpl.) Cogn. $\bar{\Delta} = 0.88$, $\bar{P} = 10.6$
Feb. 9, $\Delta = 0.84$, $P = 10.1$; Feb. 11, $\Delta = 0.84$, $P = 10.1$; Mar. 11, $\Delta = 0.97$, $P = 11.7$.
Myroxylon nitidum (Hell.) Kuntze $\bar{\Delta} = 1.35$, $\bar{P} = 16.2$
Mar. 9, $\Delta = 1.40$, $P = 16.8$; Mar. 16, $\Delta = 1.14$, $P = 13.7$; Mar. 16, $\Delta = 1.51$, $P = 18.1$.
Ocotea jamaicensis Mez (?) Mar. 4, $\Delta = 1.08$, $P = 13.0$
Palicourea alpina (Sw.) DC. $\bar{\Delta} = 0.69$, $\bar{P} = 8.3$
Feb. 18, $\Delta = 0.55$, $P = 6.6$; Mar. 16, $\Delta = 0.83$, $P = 10.0$.
Pilea Weddellii Fawc. & Rendle Mar. 9, $\Delta = 0.67$, $P = 8.1$
Psychotria corymbosa Sw. $\bar{\Delta} = 0.76$, $\bar{P} = 9.1$
Feb. 9, $\Delta = 0.70$, $P = 8.4$; Mar. 4, $\Delta = 0.75$, $P = 9.1$; Mar. 16, $\Delta = 0.82$, $P = 9.9$.
Psychotria Harrisiana Urban Mar. 16, $\Delta = 0.83$, $P = 10.0$
Rapanea ferruginea (R. & P.) Mez $\bar{\Delta} = 1.02$, $\bar{P} = 12.3$
Feb. 9, $\Delta = 0.96$, $P = 11.6$; Mar. 16, $\Delta = 1.07$, $P = 12.9$.
In the collection of Feb. 9, young leaves gave: $\Delta = 0.89$, $P = 10.7$.
Rhododendron (cultivated) $\bar{\Delta} = 1.04$, $\bar{P} = 12.6$
Feb. 20, $\Delta = 1.01$, $P = 12.2$; Feb. 20, $\Delta = 1.07$, $P = 12.9$.
Solanum punctulatum Dunal. Mar. 13, $\Delta = 1.21$, $P = 14.5$
Vaccinium meridionale Sw. Mar. 16, $\Delta = 1.32$, $P = 15.9$
Young leaves gave: $\Delta = 1.18$, $P = 14.2$.
Wallenia calyptrata Urban $\bar{\Delta} = 0.84$, $\bar{P} = 10.1$
Feb. 9, $\Delta = 0.77$, $P = 9.3$; Mar. 16, $\Delta = 0.91$, $P = 10.9$.
Young leaves were also taken on Feb. 9 and gave: $\Delta = 0.70$, $P = 8.5$.

HERBACEOUS PLANTS

Anthurium scandens (Aubl.) Engler $\bar{\Delta} = 0.63$, $\bar{P} = 7.5$
Mar. 9, $\Delta = 0.61$, $P = 7.3$; Mar. 16, $\Delta = 0.64$, $P = 7.6$.
Begonia obliqua L. Mar. 9, $\Delta = 0.33$, $P = 4.0$
Fragaria insularis Rydb. Mar. 9, $\Delta = 1.15$, $P = 13.9$
Liabum umbellatum (L.) Sch. Bip. $\bar{\Delta} = 0.71$, $\bar{P} = 8.5$
Mar. 9, $\Delta = 0.69$, $P = 8.3$; Mar. 16, $\Delta = 0.72$, $P = 8.7$.
Peperomia stellata (Sw.) A. Dietr. Mar. 9, $\Delta = 0.45$, $P = 5.4$
Pilea grandifolia (L.) Blume $\bar{\Delta} = 0.64$, $\bar{P} = 7.7$
Feb. 9, $\Delta = 0.61$, $P = 7.3$; Feb. 18, $\Delta = 0.63$, $P = 7.6$; Mar. 9, $\Delta = 0.67$, $P = 8.1$.
Plantago lanceolata L. Feb. 24, $\Delta = 1.15$, $P = 13.8$
Senites Zeugites (L.) Nash Mar. 9, $\Delta = 0.68$, $P = 8.2$

IV. *Windward Ravines and Slopes*

The windward slopes and ravines, exposed as they are to the direct influence of the moisture-laden trade winds, exhibit in the highest degree the features of climate and vegetation which find their simplest expression in the term *Rain Forest*. The mere statement of the rainfall in inches per year conveys no adequate impression of the actual environment to which the species constituting this vegetation are exposed. The roots of the plants are not merely supplied with water by the heavy and well-distributed rainfall, much of which is stored for long periods in the litter of the forest floor, but the foliage is for much of the time immersed in the floating fog. Thus insolation is much reduced. Even at times when rain is not falling and when the plants are not enveloped in fog, high atmospheric moisture is maintained for long periods of time by evaporation from the litter on the ground and from the moist foliage. Here are large trees with trunks and branches burdened with thin-leaved, succulent-leaved and tank epiphytes, with mats of hepatics and garlands of mosses and filmy ferns, shading a nearly bare forest floor or in other places overtopping a tangled shrubby and herbaceous undergrowth. Any adequate description of this forest would not only outrun the space here available but in view of Shreve's carefully penned description and well chosen and admirably executed plates is quite superfluous. One feature plates cannot depict. This is the reeking wetness of the foliage. This can only be fully appreciated by one who has had the aesthetic pleasure and the physical discomfort of collecting in these forests during or immediately subsequent to the gentle rains, which drip from the glossy foliage, percolate through the sponge-like beds of

mosses and hepatics and replenish the tank leaves of the bromeliads, if they are not already overflowing, or in the fog which rolls like clouds of smoke among the trees, covering the leaves like dew.

Ligneous Plants

Actinophyllum Sciadophyllum (Sw.) R. C. Schneider $\bar{\Delta} = 1.30$, $\bar{P} = 15.7$
Feb. 4, $\Delta = 1.12$, $P = 13.5$; Mar. 2, $\Delta = 1.48$, $P = 17.8$.

Besleria lutea L. $\bar{\Delta} = 0.58$, $\bar{P} = 7.0$
Feb. 4, $\Delta = 0.48$, $P = 5.7$; Feb. 4, $\Delta = 0.60$, $P = 7.2$; Feb. 13, $\Delta = 0.52$, $P = 6.3$; Feb. 22, $\Delta = 0.59$, $P = 7.1$; Mar. 2, $\Delta = 0.64$, $P = 7.7$; Mar. 13, $\Delta = 0.67$, $P = 8.0$.

Blakea trinervia L. $\bar{\Delta} = 0.58$, $\bar{P} = 6.9$
Feb. 13, $\Delta = 0.42$, $P = 5.0$; Mar. 2, $\Delta = 0.55$, $P = 6.7$; Mar. 2, $\Delta = 0.67$, $P = 8.1$; Mar. 13, $\Delta = 0.66$, $P = 7.9$.

Cestrum hirtum Sw. Mar. 13, $\Delta = 0.72$, $P = 8.7$

Clibadium terebinthinaceum (Sw.) DC. $\bar{\Delta} = 0.60$, $\bar{P} = 7.3$
Feb. 13, $\Delta = 0.48$, $P = 5.8$; Feb. 22, $\Delta = 0.65$, $P = 7.9$; Mar. 3, $\Delta = 0.67$, $P = 8.1$.

Clusia havetioides (Griseb.) Tr. & Pl. $\bar{\Delta} = 0.74$, $\bar{P} = 8.9$
Feb. 20, $\Delta = 0.76$, $P = 9.1$; Feb. 20, $\Delta = 0.72$, $P = 8.6$.

Cyathea furfuracea Baker $\bar{\Delta} = 0.78$, $\bar{P} = 9.5$
Feb. 24, $\Delta = 0.81$, $P = 9.8$; Feb. 24, $\Delta = 0.76$, $P = 9.2$.

Datura suaveolens H. & B. Feb. 13, $\Delta = 0.47$, $P = 5.7$

Dendropanax nutans (Sw.) Dec. & Pl. Mar. 2, $\Delta = 1.06$, $P = 12.8$
Young leaves from the same tree gave slightly lower values: $\Delta = 0.91$, $P = 10.9$.

Eupatorium glandulosum H. B. K. $\bar{\Delta} = 0.64$, $\bar{P} = 7.7$
Feb. 22, $\Delta = 0.54$, $P = 6.5$; Mar. 2, $\Delta = 0.62$, $P = 7.4$; Mar. 4, $\Delta = 0.76$, $P = 9.1$.

Eupatorium parviflorum Sw. Mar. 2, $\Delta = 1.07$, $P = 129.$

Eupatorium riparium Regel $\bar{\Delta} = 0.58$, $\bar{P} = 7.1$
Mar. 2, $\Delta = 0.55$, $P = 6.7$; Mar. 13, $\Delta = 0.61$, $P = 7.4$.

Gesneria alpina Urban $\bar{\Delta} = 0.51$, $\bar{P} = 6.2$
Mar. 2, $\Delta = 0.50$, $P = 6.1$; Mar. 13, $\Delta = 0.52$, $P = 6.3$.

Guarea Swartzii DC. $\bar{\Delta} = 0.83$, $\bar{P} = 10.0$
Feb. 13, $\Delta = 0.73$, $P = 8.8$; Feb. 22, $\Delta = 0.91$, $P = 11.0$; Mar. 13, $\Delta = 0.84$, $P = 10.1$.

Hedyosmum arborescens Sw. $\bar{\Delta} = 0.65$, $\bar{P} = 7.9$
Feb. 4, $\Delta = 0.56$, $P = 6.8$; Feb. 4, $\Delta = 0.49$, $P = 5.9$; Feb. 13, $\Delta = 0.55$, $P = 6.7$; Feb. 20, $\Delta = 0.64$, $P = 7.7$; Mar. 2, $\Delta = 0.66$, $P = 8.0$; Mar. 2, $\Delta = 0.70$, $P = 8.4$; Mar. 4, $\Delta = 0.65$, $P = 7.8$; Mar. 13, $\Delta = 0.82$, $P = 9.9$; Mar. 13, $\Delta = 0.82$, $P = 9.9$.

Marcgravia Brownei (Tr. & Pl.) Krug. & Urban. $\bar{\Delta} = 0.78$, $\bar{P} = 9.4$
Feb. 4, $\Delta = 0.62$, $P = 7.5$; Feb. 13, $\Delta = 0.65$, $P = 7.8$; Feb. 22, $\Delta = 0.67$, $P = 8.1$; Mar. 2, $\Delta = 0.85$, $P = 10.2$; Mar. 4, $\Delta = 0.87$, $P = 10.5$; Mar. 13, $\Delta = 1.02$, $P = 12.2$.

The foregoing determinations on which the average for the species is based are from the leaves of the aerial branches, extending from the trunks. Two determinations on the "juvenile" leaves of the creeping stems were secured. These are:

Feb. 13, $\Delta = 0.53$, $P = 6.4$; Mar. 4, $\Delta = 0.71$, $P = 8.5$.

Meriania purpurea Sw. $\bar{\Delta} = 0.87$, $\bar{P} = 10.5$

Feb. 22, $\Delta = 0.77$, $P = 9.3$; Mar. 2, $\Delta = 0.90$, $P = 10.8$; Mar. 13, $\Delta = 0.95$, $P = 11.5$.

Miconia quadrangularis (Sw.) Naud. Mar. 13, $\Delta = 0.97$, $P = 11.7$

Miconia theaezans (Bonpl.) Cogn. $\bar{\Delta} = 0.90$, $\bar{P} = 10.8$

Feb. 4, $\Delta = 0.76$, $P = 9.1$; Mar. 13, $\Delta = 0.97$, $P = 11.7$; Mar. 13, $\Delta = 0.96$, $P = 11.5$.

Palicourea alpina (Sw.) DC. $\bar{\Delta} = 0.69$, $\bar{P} = 8.3$

Feb. 13, $\Delta = 0.52$, $P = 6.3$; Feb. 24, $\Delta = 0.78$, $P = 9.3$; Mar. 2, $\Delta = 0.63$, $P = 7.6$; Mar. 4, $\Delta = 0.75$, $P = 9.0$; Mar. 13, $\Delta = 0.77$, $P = 9.2$.

Pilea Weddellii Fawc. & Rendle $\bar{\Delta} = 0.62$, $\bar{P} = 7.4$

Feb. 22, $\Delta = 0.57$, $P = 6.8$; Feb. 24, $\Delta = 0.67$, $P = 8.1$; Mar. 4, $\Delta = 0.61$, $P = 7.3$.

Piper hispidum Sw. $\bar{\Delta} = 0.50$, $\bar{P} = 6.1$

Feb. 13, $\Delta = 0.43$, $P = 5.2$; Feb. 22, $\Delta = 0.45$, $P = 5.4$; Mar. 13, $\Delta = 0.63$, $P = 7.6$.

Podocarpus Urbani Pilger Feb. 24, $\Delta = 0.93$, $P = 11.2$

Young leaves gave: $\Delta = 0.81$, $P = 9.7$.

Psychotria corymbosa Sw. $\bar{\Delta} = 0.76$, $\bar{P} = 9.2$

Feb. 20, $\Delta = 0.75$, $P = 9.0$; Mar. 4, $\Delta = 0.67$, $P = 8.1$; Mar. 13, $\Delta = 0.86$, $P = 10.4$.

Schradera involucrata (Sw.) Schum. Mar. 13, $\Delta = 1.24$, $P = 15.0$

Solanum punctulatum Dunal Mar. 13, $\Delta = 1.14$, $P = 13.8$

Tovaria pendula R. & P. $\bar{\Delta} = 0.70$, $\bar{P} = 8.5$

Feb. 13, $\Delta = 0.68$, $P = 8.2$; Feb. 22, $\Delta = 0.72$, $P = 8.7$.

Vaccinium meridionale Sw. $\bar{\Delta} = 1.33$, $\bar{P} = 16.1$

Mar. 2, $\Delta = 1.31$, $P = 15.8$; Mar. 13, $\Delta = 1.36$, $P = 16.3$.

Herbaceous Plants

Anthurium scandens (Aubl.) Engler $\bar{\Delta} = 0.52$, $\bar{P} = 6.3$

Feb. 13, $\Delta = 0.50$, $P = 6.0$; Mar. 4, $\Delta = 0.52$, $P = 6.2$; Mar. 13, $\Delta = 0.55$, $P = 6.6$.

Begonia glabra Aubl. $\bar{\Delta} = 0.30$, $\bar{P} = 3.5$

Feb. 4, $\Delta = 0.29$, $P = 3.4$; Feb. 13, $\Delta = 0.30$, $P = 3.6$.

Begonia obliqua L. $\bar{\Delta} = 0.33$, $\bar{P} = 3.9$

Feb. 20, $\Delta = 0.31$, $P = 3.7$; Feb. 24, $\Delta = 0.33$, $P = 4.0$; Mar. 2, $\Delta = 0.35$, $P = 4.2$; Mar. 4, $\Delta = 0.32$, $P = 3.8$; Mar. 13, $\Delta = 0.35$, $P = 4.2$; Mar. 13, $\Delta = 0.31$, $P = 3.7$.

Elaphoglossum chartaceum Baker Mar. 13, $\Delta = 0.96$, $P = 11.5$

Fragaria insularis Rydb. Mar. 13, $\Delta = 1.09$, $P = 13.1$

Gesneria mimuloides (Griseb.) Urban $\bar{\Delta} = 0.44$, $\bar{P} = 5.2$

Mar. 2, $\Delta = 0.42$, $P = 5.0$; Mar. 4, $\Delta = 0.45$, $P = 5.4$.

Liabum umbellatum (L.) Sch. Bip. $\bar{\Delta} = 0.58$, $\bar{P} = 7.0$
Mar. 2, $\Delta = 0.53$, $P = 6.4$; Mar. 4, $\Delta = 0.60$, $P = 7.2$; Mar. 13, $\Delta = 0.62$, $P = 7.5$.

Lobelia assurgens L. $\bar{\Delta} = 0.73$, $\bar{P} = 8.7$
Feb. 13, $\Delta = 0.66$, $P = 8.0$; Mar. 2, $\Delta = 0.76$, $P = 9.1$; Mar. 2, $\Delta = 0.76$, $P = 9.1$.

Panicum palmifolium Poir. $\bar{\Delta} = 0.80$, $\bar{P} = 9.6$
Feb. 4, $\Delta = 0.76$, $P = 9.2$; Feb. 22, $\Delta = 0.80$, $P = 9.7$; Mar. 2, $\Delta = 0.83$, $P = 10.0$.

Peperomia stellata (Sw.) A. Dietr. $\bar{\Delta} = 0.42$, $\bar{P} = 5.1$
Mar. 2, $\Delta = 0.42$, $P = 5.1$; Mar. 4, $\Delta = 0.41$, $P = 4.9$; Mar. 13, $\Delta = 0.43$, $P = 5.2$.

Pilea Mar. 4, $\Delta = 0.65$, $P = 7.9$

Pilea grandifolia (L.) Blume $\bar{\Delta} = 0.58$, $\bar{P} = 7.0$
Feb. 13, $\Delta = 0.57$, $P = 6.8$; Feb. 22, $\Delta = 0.59$, $P = 7.1$.

Pilea nigrescens Urban $\bar{\Delta} = 0.57$, $\bar{P} = 6.9$
Feb. 20, $\Delta = 0.56$, $P = 6.7$; Feb. 22, $\Delta = 0.51$, $P = 6.1$; Feb. 24, $\Delta = 0.55$, $P = 6.6$; Mar. 2, $\Delta = 0.58$, $P = 6.9$; Mar. 4, $\Delta = 0.61$, $P = 7.4$; Mar. 13, $\Delta = 0.61$, $P = 7.4$.

Prescottia stachyodes (Sw.) Lindl. $\bar{\Delta} = 0.81$, $\bar{P} = 9.7$
Feb. 24, $\Delta = 0.84$, $P = 10.1$; Mar. 4, $\Delta = 0.72$, $P = 8.6$; Mar. 13, $\Delta = 0.87$, $P = 10.5$.

Senites Zeugites (L.) Nash $\bar{\Delta} = 0.62$, $\bar{P} = 7.4$
Feb. 24, $\Delta = 0.59$, $P = 7.1$; Mar. 4, $\Delta = 0.64$, $P = 7.8$.

III. Discussion of Results

In analyzing these data we shall consider three main problems:

A. The relationship between growth form and osmotic concentration.

B. The differentiation of the habitats of the Blue Mountains in osmotic concentration.

C. The relative value of the osmotic concentration of the fluids of the plants of the Blue Mountain rain forest as compared with other phytogeographically different areas which have been investigated by similar methods.

The only method by which these problems may be investigated is the statistical one, the comparison by means of averages of different sections of the data.

The averages of species means (or of species determinations, when only one for a habitat is available) are given for herbaceous and ligneous plants separately, and for all plants, for each of the four habitats in Table I.

TABLE I

Fundamental Averages for Blue Mountain Rain Forest

Habitats and Constants	Ligneous Plants		Herbaceous Plants		Ligneous and Herbaceous Plants	
	Number	Mean	Number	Mean	Number	Mean
I. Ruinate of leeward slopes:						
Freezing-point lowering......	40	1.089	17	.812	57	1.007
Osmotic concentration.......		13.05		9.77		12.07
II. Leeward ravines:						
Freezing-point lowering......	32	.901	13	.628	45	.822
Osmotic concentration.......		10.83		7.59		9.89
III. The ridge forest:						
Freezing-point lowering......	36	.958	8	.718	44	.914
Osmotic concentration.......		11.54		8.63		11.01
IV. Windward ravines and slopes:						
Freezing-point lowering......	28	.805	15	.627	43	.743
Osmotic concentration.......		9.73		7.52		8.96
I–IV. All species:						
Freezing-point lowering......	136	.952	53	.700	189	.881
Osmotic concentration.......		11.44		8.80		10.59

These are the fundamental constants upon which much of the following discussion must be based.

Comparison of Ligneous and Herbaceous Growth Forms.—The justification for the division of the determinations into those for herbaceous and those for ligneous plants is clearly brought out by Table I. For each habitat studied the freezing point lowering is on the average lower for the herbaceous than for the ligneous plants. The actual differences in terms of atmospheres are given in Table II.

TABLE II

Comparison of Osmotic Concentration of Herbaceous and Ligneous Growth Forms

Growth Form	Ruinate of the Leeward Slopes	Leeward Ravines	Ridge Forest	Windward Slopes and Ravines	All Habitats
All species....................	12.07	9.89	11.01	8.96	10.59
Ligneous species..............	13.05	10.83	11.54	9.73	11.44
Herbaceous species............	9.77	7.59	8.63	7.52	8.80
Difference....................	3.28	3.24	2.91	2.21	2.64
Percentage difference..........	25.13	29.92	25.22	22.71	23.08

Thus the difference in the concentration of the sap of ligneous and herbaceous plants is from about 23 to about 30 percent of the higher value, that for ligneous forms.

Comparison of Habitats in the Blue Mountain Region.—Turning

now to the comparisons of the local habitats among themselves we note the following points which must be taken into consideration in the analysis of the data.

The comparisons between the windward and the leeward exposures on the basis of the now available data may be expected to give a minimum rather than a maximum measure of the differences between them. This is true for three reasons. First, we have made the comparison between the plants of the windward slopes and windward ravines taken together and two of the sub-habitats of the leeward slopes. Thus if there be measurable differences between the sap properties of the windward ravines and the windward slopes, the combination of the two will tend to minimize the differences which might have been obtained had it been practicable to deal separately with the properties of the saps of the windward slopes and ravines. Second, we have arbitrarily excluded a great number of forms which are apparently the most hygrophilous and are possibly characterized by an even lower osmotic concentration than are the species for which determinations are given in these pages. Had it been possible to free the mats or festoons of certain of the cryptogamic epiphytes from the superficial water with which they are so constantly saturated, without modifying the concentration of their tissue solutions by drying, we believe that a series of determinations falling almost if not entirely in the lower range of variation in osmotic concentration as shown by the available determinations might have been obtained. Third, to render the results from the Blue Mountain habitats as nearly as possible comparable with others which have been or are being investigated we have excluded the Bromeliaceae, the Orchidaceae, with the exception of truly terrestrial forms, and some other phanerogamic epiphytes. There is, as far as we are aware, no *a priori* reason to consider that these forms would be characterized by low osmotic concentrations. While the detailed discussion of these ecologically most interesting forms is reserved for a comparative study to be published later, it may be said in passing that the concentration of these forms has been found to be usually far lower than that of other species of the vegetation.

These facts while they must detract somewhat from our constants as an exact description of the region in question, make differences secured under these limitations much more significant.

In considering differences in sap concentration in relation to local

habitats in the rain-forest region the comparison of each of the four habitats with the three others may be made in detail in a series of four tables.

In view of the differentiation between herbaceous and ligneous plants demonstrated above, the comparison must first be made for each class separately.

In these tables each of which is devoted to the values showing the absolute and relative magnitudes of the constants of a given habitat, the comparisons are made in two ways. First, the actual differences in mean osmotic concentration, $\overline{P}$, between any habitat and the three other habitats have been determined. These are the values with signs. Second, the ratio of the mean osmotic concentration of the sap of every habitat to that of each other habitat with which it is to be compared has been determined. These are the values given in black-faced type.

The first method has the obvious advantage that differences are expressed in the concrete terms of osmotic concentration. Relative values, as employed in the second method, are on the other hand more convenient for comparison. The exact method of drawing the comparisons will be clear from an explanation of the individual tables.

The first column of Table III, in which the values obtained in the

TABLE III

Growth Form	Ruinate of the Leeward Slopes	Ruinate of the Leeward Slopes Compared with Other Habitats			
		Leeward Ravines	Ridge Forest	Windward Slopes and Ravines	All Habitats
Herbaceous....	9.77	+2.18	+1.14	+2.25	+0.97
	1.00	**1.29**	**1.13**	**1.30**	**1.11**
Ligneous.......	13.05	+2.22	+1.51	+3.32	+1.61
	1.00	**1.20**	**1.13**	**1.34**	**1.14**
All species.....	12.07	+2.18	+1.06	+3.11	+1.48
	1.00	**1.22**	**1.10**	**1.35**	**1.14**

ruinate of the leeward slopes are compared with those of each of the other habitats, gives the growth forms on which the comparisons are based. It has been practicable to recognize only two of these in the Blue Mountain region, the herbs and arborescent, frutescent and suffrutescent plants. The second column gives the actual mean values in atmospheres of the plants of the ruinate. The third to

sixth columns contain the actual differences between the mean values for the plants of the ruinate and of the three other habitats and of the region as a whole. These are obtained by subtracting the values for each of the habitats compared from the values for the ruinate as given in the second column. The same method is followed in drawing up the three other comparison tables to be discussed below.

The signs of the differences are positive throughout. Thus the concentrations prevailing in the plants of the ruinate, which has been recognized by Shreve and others as the most xerophilous of the Blue Mountain habitats, are higher for both herbaceous and ligneous plants and for all species of plants than those in any other habitat. They are over two atmospheres higher than those found in the plants of the neighboring leeward ravines, over one atmosphere higher than those of the ridge forest and from over two to more than three atmospheres higher than those demonstrated on the windward side of the range.

The relative values, obtained by dividing the mean concentration of the plants of the ruinate by those of each of the other habitats, show that the concentration of the sap of the plants of the most xerophytic of the habitats is from about 20 to 30 percent more concentrated than that of the leeward ravines, about 10–13 percent more concentrated than that of the ridge forest, and from 30 to 35 percent more concentrated than that of the plants of the windward habitats.

Table IV, giving the relationship between the sap properties of

TABLE IV

Growth Form	Ridge Forest	Ridge Forest Compared with Other Habitats			
		Ruinate of Leeward Slopes	Leeward Ravines	Windward Slopes and Ravines	All Habitats
Herbaceous....	8.63	−1.14	+1.04	+1.11	−0.17
	1.00	**0.88**	**1.14**	**1.15**	**0.98**
Ligneous.......	11.54	−1.51	+0.71	+1.81	+0.10
	1.00	**0.88**	**1.15**	**1.19**	**1.01**
All species.....	11.01	−1.06	+1.12	+2.05	+0.42
	1.00	**0.91**	**1.11**	**1.23**	**1.04**

the plants of the ridge forest and those of the other habitats, shows that the plants of this habitat have a concentration lower than that of the comparable growth forms of the ruinate but higher than that of either the leeward ravines or the windward ravines and slopes. The amount of the difference is as great as 2 atmospheres in one case only.

The relative differences are not large. In only a single comparison does the ratio indicate a difference of as much as 23 percent.

Table V shows that the concentration in the plants of the leeward ravines is lower than in those of the ruinate or of the ridge forest

TABLE V

Growth Form	Leeward Ravines	Leeward Ravines Compared with Other Habitats			
		Ruinate of Leeward Slopes	Ridge Forest	Windward Slopes and Ravines	All Habitats
Herbaceous....	7.59	−2.18	−1.04	+0.07	−1.21
	1.00	**0.78**	**0.88**	**1.01**	**0.86**
Ligneous.......	10.83	−2.22	−0.71	+1.10	−0.61
	1.00	**0.83**	**0.94**	**1.11**	**0.95**
All species.....	9.89	−2.18	−1.12	+0.93	−0.70
	1.00	**0.82**	**0.90**	**1.10**	**0.93**

but higher than that of the windward slopes and ravines. The differences between the concentrations in the leeward ravines and on the ridges on the one hand and between the leeward ravines and the windward ravines on the other are not large.

The final comparison is that of the windward ravines and slopes with the other habitats. This is made in Table VI. The differences show that the plants of the most hygrophytic habitat of the region

TABLE VI

Growth Form	Windward Slopes and Ravines	Windward Slopes and Ravines Compared with Other Habitats			
		Ruinate of Leeward Slopes	Leeward Ravines	Ridge Forest	All Habitats
Herbaceous....	7.52	−2.25	−0.07	−1.11	−1.28
	1.00	**0.77**	**0.99**	**0.87**	**0.85**
Ligneous.......	9.73	−3.32	−1.10	−1.81	−1.71
	1.00	**0.75**	**0.90**	**0.84**	**0.85**
All species.....	8.96	−3.11	−0.93	−2.05	−1.63
	1.00	**0.74**	**0.91**	**0.81**	**0.85**

under investigation are characterized by a lower osmotic concentration than those of any other habitat. To this rule there is not a single exception. The values range from 74 to 99 percent of that of other habitats.

Comparison of Blue Mountain Rain Forest with Other Regions.—Our work in Jamaica was undertaken primarily to secure determinations from an extremely hygrophytic habitat for comparison with the

xerophytic region about the Desert Laboratory at Tucson and the more mesophytic vegetation in the neighborhood of the Station for Experimental Evolution on Long Island.

Since carrying out the Jamaican determinations we have been able to make very substantial beginnings on the investigation of several other habitats, for example the forests of the upper Santa Catalina mountains and the various transition stations to the desert floor in southern Arizona, the Everglades, the Pinelands, and the hammocks of sub-tropical Florida, rich in West Indian species. A detailed comparison of the montane rain forest with other regions may profitably be reserved until the completion of these studies. In the meantime it is worth while to indicate to phytogeographers and ecologists the relative position of the Blue Mountain habitats in the series concerning which published data are available.

Consider first the values for the rain-forest plants as compared with those obtained in more mesophytic regions. Two such series are available, that of Ohlweiler ('12) based on trees and shrubs growing at the Missouri Botanical Garden, and that of Harris, Lawrence and Gortner ('15) for Long Island habitats.

Ohlweiler's St. Louis series suffers from two disadvantages as regarded from the standpoint of this paper. First, it is based upon a series of species brought together from various natural habitats and cultivated in a botanical garden. All the species were, however, capable of growth in the open under the conditions prevailing at St. Louis. Second, sap was extracted without antecedent freezing of the leaf tissue. As a result the freezing-point lowerings recorded are probably too low.

Ohlweiler's series comprises trees and shrubs only. Comparing with the general average for ligneous plants from the Blue Mountains the results are:

	Means
St. Louis series	14.96
Blue Mountain series	11.44

The trees and shrubs growing in the Botanical Garden at St. Louis show, therefore, a concentration of their leaf sap of from 2 to 5 atmospheres higher than do those of the various Blue Mountain habitats, and over 3 atmospheres more than the average for the Blue Mountain region as a whole.

The averages for the Long Island series[2] have been calculated for individual habitats. The averages for both trees and shrubs and for herbaceous plants may be compared with the individual Blue Mountain habitats. The means of the accompanying tables, VII–VIII,

TABLE VII

Comparison of Ligneous Plants

Jamaican Habitats			Long Island Habitats
Ruinate	13.05	13.34	Beaches, coastal sand dunes and marshes
Ridge forest	11.54	14.64	Dryer woods and open fields
Leeward ravines	10.83		
Windward habitats	9.73	14.07	Permanently moist localities
All habitats	11.44	14.40	All habitats

TABLE VIII

Comparison of Herbaceous Plants

Jamaican Habitats			Long Island Habitats
Ruinate	9.77	13.62	Beaches, coastal sand dunes and marshes
Ridge forest	8.63	10.04	Dryer woods and open fields
Leeward ravines	7.59		
Windward habitats	7.52	9.27	Permanently moist localities
All habitats	8.80	10.41	All habitats

show that with the exception of the herbaceous plants of the ruinate there is no habitat of the Blue Mountain region which exhibits an osmotic concentration of the leaf sap of the species constituting its flora as high as the lowest mean found in the Cold Spring Harbor series. The herbaceous plants of the ruinate—the most xerophytic of the Blue Mountain habitats—show a concentration slightly higher than those of the Long Island habitats which are constantly moist, *i. e.*, fresh water bogs, lake shores and springy hillsides.

[2] The values given for Cold Spring Harbor are preliminary averages of determinations, not of species means, made in 1914 by Harris, Lawrence and Gortner. They will be replaced later by averages based on far larger series of determinations made in 1915 by Lawrence and Harris, and on subsequent determinations by Harris.

In view of the fact that the Long Island series here used is to be much increased, further discussion of the observed differences may be postponed until the more extensive data are worked up.

A conspicuous difference in the osmotic concentration of rain-forest and desert vegetation is of course to be expected after the demonstration of the differentiation of the sap properties of the plants of this and more mesophytic regions. Two fairly satisfactory sets of determinations for deserts are now available. The magnitude of the differences between the rain forest and these will give some indication of the range of variation to be found in the mean osmotic concentration of the fluids of the species of different vegetations.

A comparison with the Arizona desert series of determinations made at the time of hibernal and vernal vegetative activity[3] is made in the accompanying tables, IX–X. In these, averages[4] are given for

TABLE IX

Comparison for Ligneous Perennials

Jamaican Habitats		Arizona Habitats	
Ruinate	13.05	22.01	Rocky slopes
Ridge forest	11.54	21.04	Canyons
Leeward ravines	10.83	17.30	Arroyos
Windward habitats	9.73		
		30.34	Bajada slopes
		45.20	Salt spots
All habitats	11.44	24.97	All habitats

TABLE X

Comparison for Herbaceous Plants

Jamaican Habitats		Arizona Habitats	
Ruinate	9.77	15.94	Rocky slopes
Ridge forest	8.63	13.33	Canyons
Leeward ravines	7.59	12.99	Arroyos
Windward habitats	7.52		
		20.53	Bajada slopes
		23.57	Salt spots
All habitats	8.80	15.15	All habitats

[3] Studies on the summer vegetation have been made and will eventually be published.

[4] The averages for the southwestern deserts are based on species determinations, not on means of determinations as in the Jamaica series. The difference in method is of no significance for present purposes.

each of the sub-habitats for both ligneous and herbaceous forms. In our original paper (Harris, Lawrence and Gortner, 1916) the determinations for the ligneous plants are further subdivided into trees and shrubs as one class and dwarf shrubs, half shrubs and woody twiners as the other. Such distinctions have not been so easily made in the rain forest. The two groups of desert ligneous perennials have, therefore, been combined to render them more comparable with the Jamaica ligneous perennials.

The Arizona herbaceous plants were originally divided into the two very distinct groups, winter annuals and perennial herbs. These have also been combined to render them more nearly comparable with the herbaceou plants of the Blue Mountain region.

Of course no one of the desert habitats is at all similar to those of the Blue Mountains. Those which are least of all comparable, the bajadas and the salt spots, have been set off from the others.

The tables show at a glance that the concentrations of the desert are from fifty to nearly two hundred percent higher for individual habitats in the Arizona deserts than in the Jamaica Blue Mountains.

The differences between the two regions are strikingly exemplified by a comparison of the herbaceous plants of the desert with the ligneous plants of the rain forest. The *minimum* osmotic concentration in desert herbaceous plants (12.99 atmospheres in the arroyos) is practically as high as the *maximum* concentration for ligneous plants in the Blue Mountains (13.05 atmospheres in the ruinate). The mean concentration for herbaceous plants in the desert is 15.15 atmospheres as compared with 11.44 atmospheres, the mean concentration of ligneous plants in the Blue Mountains.

While logically a comparison of the rain-forest vegetation of the Blue Mountains with the desert vegetation of the coastal deserts has no greater significance than that with the vegetation of the Arizona deserts it will, because of the relatively short distance separating the two Jamaican habitats, have a greater interest for most readers.

The comparison with the coastal desert of the southern shore of Jamaica (Harris and Lawrence, 1917) must be limited to ligneous perennials. The average of the 31 species means for arborescent and suffrutescent plants of the coastal desert, omitting only the herbaceous *Sesuvium*, *Bromelia*, *Bryophyllum* and the Cacti, is 30.05 atmospheres, as compared with 11.44 atmospheres for the montane habitats!

Very high concentrations are also found in the mangrove swamps

on the southern shore of Jamaica (Harris and Lawrence, 1917*b*). Thus *Rhizophora Mangle* shows concentrations ranging from 29.2 to 30.9 atmospheres, *Laguncularia racemosa* shows concentrations ranging from 24.6 to 34.8 atmospheres and *Avicennia nitida* yields values from 41.5 to 54.4 atmospheres.

IV. Recapitulation

The Blue Mountains of Jamaica, intercepting as they do the trade winds in their sweep across the Caribbean Sea, exhibit a conspicuous differentiation in the flora and especially in the vegetation of the windward (northern) and the leeward (southern) sides of the range.

The windward slopes, and especially the windward ravines, exhibit all those features of vegetation and of structure of the constituent species which are called to the mind of the botanist by the term *Rain Forest.* In the higher mountains the leeward ravines share many of the characteristics of the windward ravines and slopes, but the leeward slopes, and especially the scrub formation known as ruinate, are far more xerophytic in their botanical characteristics.

The subalpine ridges, while lacking some of the most characteristic and typical xerophytic species of the ruinate, are nevertheless clearly far more xerophytic than either the windward slopes or ravines or the leeward ravines.

These differences have long been known to botanists, and have recently been splendidly described and illustrated by Shreve.

The purpose of the investigations described in this paper, which is one of a series on the sap properties of the plant species of diverse vegetations, is to present the results of an extensive series of cryoscopic determinations of osmotic concentration of leaf sap in the species of the Blue Mountains, to compare these habitats among themselves on the basis of the average osmotic concentration of their leaf tissue fluids, and to compare the region as a whole with other areas, mesophytic and xerophytic, which have been investigated in a similar manner.

The results of the present study confirm the conclusions concerning the existence of a higher osmotic concentration in the tissue fluids of the leaves of ligneous than in those of the tissue fluids of herbaceous plants, drawn from the investigation of the deserts of southern Arizona. The difference between the concentration of the sap of the two groups

of growth forms is clearly marked in the series of determinations from each of the Blue Mountain habitats. The differences are not, however, so large as those demonstrated in the desert series.

The four sub-habitats, recognized in the Blue Mountains, show distinct differences in the osmotic concentration of their tissue fluids.

The ruinate, which has been regarded by ecologists as the most xerophytic of the habitats, shows a distinctly higher osmotic concentration of the leaf tissue fluids of its constituent species than any other habitat. The plants of the ridge forest show a higher osmotic concentration than do those of the leeward ravines and the windward ravines and slopes, but lower than that of the plants of the ruinate. The leeward ravines are characterized by plants with lower osmotic concentration than the vegetation of the ruinate and of the ridge forest, but higher than that of the windward ravines and slopes. Finally, the windward habitats, which are the most hygrophilous of the region, are characterized by a sap concentration lower than that of any other habitat.

The osmotic concentration in the sap of the plants of the Blue Mountains is the lowest of that of any region as yet extensively investigated. The ligneous forms show an average concentration of about 11.44 atmospheres as compared with 14.96 atmospheres in Ohlweiler's St. Louis series and 14.40 for our own preliminary series from Long Island habitats. The average concentration for herbaceous plants in the Blue Mountains is about 8.80 atmospheres as compared with 10.41 atmospheres from our preliminary Long Island series.

Comparisons with desert regions show much more striking differences. Thus the herbaceous plants of the rain forest show an average concentration of 8.80 atmospheres as compared with 15.15 atmospheres in the herbaceous plants of the winter flora of the deserts around Tucson. The ligneous plants of the rain forest have a concentration of only about 11.44 atmospheres as contrasted with 24.97 atmospheres in the series of ligneous plants investigated in our southwestern deserts. The Jamaican coastal deserts show slightly higher concentration even than those of the Arizona series.

While these general averages are the simplest expression of the differences between these regions, they are by no means an adequate description. They conceal the differences which obtain in each of the areas investigated. For a more adequate conception of the conditions, the reader must turn to the more detailed comparisons

which are made possible by the data presented earlier in these pages, and in the original papers to which reference has been made.

Further comparisons will be made when the data from other field work are properly arranged for discussion.

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